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Monitoring Wetland Functional Recovery of Bottomland Hardwood Sites in the Yazoo Basin, MS

by Monica N. Humphrey, Jeff P. Lin, Barbara A. Kleiss, and Darrell E. Evans

PURPOSE: The U.S. Army Corps of Engineers (USACE) Vicksburg District has the task of mitigating functions of bottomland hardwood (BLH) wetland forests in Mississippi lost as a result of the construction of various water resource projects. To date, the Vicksburg District has reforested almost 20,000 acres of BLH forest. This technical note reports on early functional recovery and monitoring at several of these sites, utilizing methodology based on "The Regional Guidebook for Conducting Functional Assessments Based on Hydrogeomorphic (HGM) Classification and Reference Wetlands for Selected Wetland Subclasses in the Yazoo Basin, Lower Mississippi River Alluvial Valley, USA" (Smith and Klimas 2002).

BACKGROUND: Since 1991, the Vicksburg District has replanted about 18,000 acres of bottomland hardwood (BLH) forest at five sites within the Yazoo Basin. This mitigation entailed planting mast-producing species such as oaks and hickories on frequently flooded former agricultural land. Because of flood frequency, these areas possess the hydric soils and sufficient hydrology necessary for the development of a functional BLH forest.

Assessing wetland functions as they develop in newly reforested areas is essential in order to determine if current methods of mitigation are accomplishing the goal of full wetland functional recovery. When measuring functions, it is desirable to have a standard methodology that is not too time-consuming or expensive to implement, but is also sensitive enough to detect a change in wetland functions over time. Generally, the most cost-effective, time-efficient and replicable option is the use of indirect indicators. These indicators convey information about the performance of a given function based on an indirect measure of that function. Indicators are most often used instead of direct measures, which are usually too time-consuming and expensive to carry out for monitoring purposes. One such methodology that uses indirect indicators is the hydrogeomorphic (HGM) functional assessment approach.

The purpose of this study was to perform a preliminary functional assessment of the Vicksburg District BLH mitigation sites. This assessment was carried out utilizing models and methods from a regional HGM guidebook developed for the Yazoo Basin (Yazoo Regional Guidebook) by Smith and Klimas (2002).

STUDY AREA: Monitoring was carried out at five mitigation sites (Figure 1) of various sizes and ages, located within the Yazoo Basin, Mississippi, and described as follows:

<u>Lake George.</u> Located in Yazoo County between the Delta National Forest and Panther Swamp National Wildlife Refuge, this is the largest of the planted tracts at a total of 8,383 acres. The site has had eight planting dates from 1991 to 1998, covering 7,668 acres. Initial plantings at this site

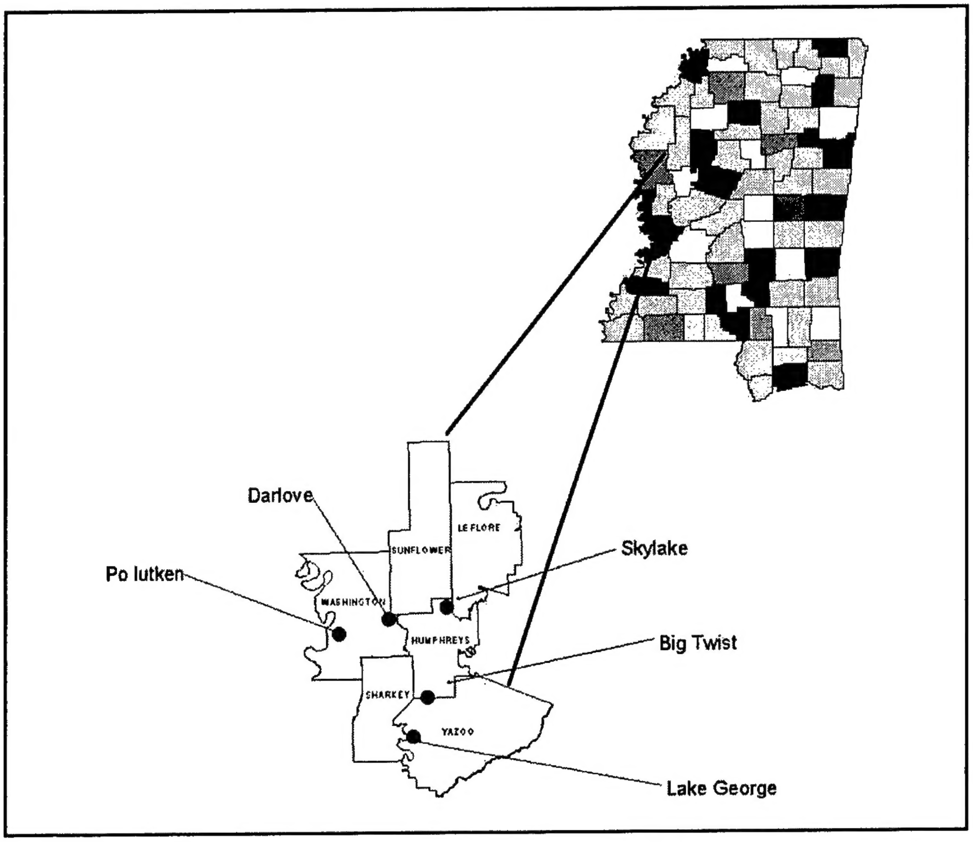

Figure 1. Location of mitigation sites in the Yazoo Basin, Mississippi

consisted of a combination of 1-0 bareroot, direct seeding and container-grown planting stock. The later plantings beginning in 1993 consisted of 1-0 bareroot and container stock only. Species planted include red oaks (*Quercus* spp.), bald cypress (*Taxodium distichum*), green ash (*Fraxinus pennsylvanica*), pecan (*Carya illinoensis*), sycamore (*Platanus occidentalis*), and water tupelo (*Nyssa aquatica*).

Big Twist. This is the second-largest tract and is located in Yazoo and Humphreys Counties. It is 6,648 acres in size and is partially bordered by Panther Swamp National Wildlife Refuge and The Will M. Whittington Canal. Seedlings planted at this site consisted only of 1-0 bareroot and container-grown seedlings, with planting beginning in 1995 and ending in 1998. A total of 5,610 acres have been planted with red oaks, bald cypress, pecan, and sycamore.

Darlove Mitigation Site. This is a 518-acre tract located in Washington County, bordered by the Bogue Phalia. The tract was planted in the 1998-1999 planting season, with a total of 490 acres of both 1-0 bareroot and container-grown seedlings. Species planted at the site include red oaks, bald cypress, and green ash.

Polutken Mitigation Site. This site is also located in Washington County. It is 333 acres in total size, with 296 acres hand planted with container seedlings in 1997. Planted species include various red oaks and bald cypress.

Skylake Mitigation Site. This site is located in Humphreys County. It consists of 2,420 acres planted with bare root seedlings in 1999. Species planted include red oaks and bald cypress.

SITE CLASSIFICATION: Since HGM functional assessment models are specific to a particular wetland subclass, it is necessary to classify sites before the model can be applied. The HGM methodology classifies wetlands based on geomorphic setting, water source, and hydrodynamics (Brinson 1993). The Yazoo Regional Guidebook identifies and describes seven regional HGM subclasses in the Yazoo Basin. Of these seven, four are found in the Vicksburg District mitigation sites: Riverine Backwater, Isolated Depressions, Connected Depressions, and Flats. Brief descriptions of each of the four subclasses follow:

Riverine Backwater. This wetland subclass is subjected to backwater flooding occurring at a frequency of five years or less. Backwater flooding is defined as inundation resulting from impeded drainage due to high water in downstream systems. Distinctive characteristics of the subclass include:

- Direct connection to a channel system with a flood frequency of at least 5 years.
- On-site flooding is a result of backwater, as opposed to overbank, flow.
- Floodwater drains back into the channel, rather than being retained on site in depressions.

This subclass supports a variety of community types and can occur on various substrates. Typical species include green ash and Nuttall oak (*Quercus nuttallii*).

Isolated Depressions. Depressions tend to occur on abandoned channels and courses and large point bar swales. Isolated depressions are not directly connected to a stream system, but receive and detain water from precipitation and surface and subsurface flows. Because of their size and depth, they are able to hold this water for extended periods of time, and dry very slowly. This wetland subclass usually exhibits two or more of the following attributes:

- Loamy gleyed matrix or hydrogen sulfide aroma hydric soil indicators.
- Topographic depression with the Dowling or Tunica soils.
- Significant vegetative component of one or more of the following: bald cypress, swamp tupelo (*Nyssa aquatica*), swamp privet (*Foresteria accuminata*), water elm (*Planera aquatica*), or buttonbush (*Cephalanthus occidentalis*).

Connected Depressions. This wetland subclass has the same characteristics as the isolated depressions subclass; however, these depressions are connected to a stream system, giving them an additional source of water.

Flats. Flats are primarily precipitation-driven systems. They can occur on a variety of depositional surfaces, but are most characteristic of point bar deposits. They tend to be the driest of the sub-classes, with shagbark hickory (*Carya ovatica*) and water oak (*Quercus nigra*) as characteristic species.

WETLAND FUNCTIONS: Smith and Klimas (2002) identify seven functions that are performed by wetlands in the Yazoo Basin:

- Detain floodwater.
- Detain precipitation.
- Cycle nutrients.
- Export organic carbon.
- Remove elements and compounds.
- Maintain plant communities.
- Provide fish and wildlife habitat.

However, not all functions are assessed for, or performed by each subclass (Table 1). A brief description of each of the functions follows:

Table 1
Functions Assessed for Each of the Wetland Subclasses Found at the Yazoo BLH Mitigation Sites

Function	Wetland Subclass: Riverine Backwater	Connected Depression	Isolated Depressions	Flats
Detain floodwater	X	X		
Detain precipitation	X			X
Cycle nutrients	X	X	X	X
Export organic carbon	X	X		
Remove elements and compounds	X	X		
Maintain characteristic plant community	X	X	X	X
Provide fish and wildlife habitat	X	X	X	X

<u>Detain Floodwater.</u> This function is the capacity of a wetland to store, convey, and reduce the velocity of floodwater. It is assessed by estimating "roughness" within the wetland, as well as flood frequency.

<u>Detain Precipitation.</u> This function is the ability of a wetland to prevent or slow runoff of rainfall to streams. The function is assessed by estimating micro-depressions storage and organic surface layer available to improve absorption and infiltration.

<u>Cycle Nutrients.</u> This function is the ability of a wetland to convert nutrients from inorganic to organic forms and back. It is assessed by measuring components of living and dead organic material in the wetland.

<u>Export Organic Carbon.</u> This function is the ability of the wetland to export dissolved and particulate organic carbon. It is assessed by measuring the presence of movable organic material and flood frequency.

<u>Remove Elements and Compounds.</u> This function is the ability of a wetland to permanently remove or temporarily immobilize elements and compounds such as macronutrient or heavy metals that are imported into the wetland. It is assessed using indicators of the clay and organic components of the soil, and flood frequency.

<u>Maintain Plant Communities.</u> This function is the ability of the wetland to provide an environment necessary to develop and maintain a plant community characteristic of the system. It is assessed using various indicators of soil, hydrologic, and vegetative characteristics of the site.

Provide Fish and Wildlife Habitat. This function is the ability of a wetland to support fish and wildlife species that utilize wetlands during some part of their life cycle. It is assessed using indicators of habitat availability and landscape integrity.

METHODS: Sampling at the mitigation sites occurred during 2000-2002.

Sampling Year 2000. The initial phase of the project involved establishing permanent monitoring plots at each mitigation site. Five rectangular 0.04-ha plots were established within each planting date at each site. A GPS reading was taken at the center of each plot for documentation and mapping purposes. Various baseline vegetation data were collected, although these data are not used in the HGM analysis.

Sampling Year 2001. The second phase of the project began with the completion in February 2001 of documentation needed to measure the indicator metrics used in the HGM functional assessment models. In the spring of 2001, a two-member sampling team visited the mitigation sites and began collecting metrics following the systematic procedure listed below:

- Identification of wetland subclass. Identifying the wetland subclass(es) in the project areas involved using a dichotomous key from the Yazoo Regional Guidebook and information from Saucier (1994). The GPS points collected from the permanent plots established in 2000 were incorporated into an ArcView GIS database and used to create a map that displayed the location of sampling plots in reference to flood frequency, soil series, and land use and land cover. Information from this map was used for initial classification of the mitigation sites.
- Define the assessment areas. The wetland assessment area (WAA) is an area of wetland within a project area that belongs to a single regional wetland subclass and is relatively homogeneous with respect to the criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage). In many areas, there will be just one WAA. However, as the size and heterogeneity of the site increase, it is more likely that it will be necessary to define and assess multiple WAAs within a project area.
- Collect field data. Variables and metrics used to assess the wetland functions are collected at several different spatial scales. Data Form 1 (Figure 2) is organized so as to facilitate data collection at each of these spatial scales. For example, the first group of variables, which includes VTRACT, contains information about landscape-scale characteristics collected using aerial photographs, maps, and field reconnaissance of the area surrounding the WAA. Information on the second group of variables, which includes VPOND, is collected during a walking reconnaissance of the WAA. Data collected for these two groups of variables are entered directly into the data form. Information on the next group of variables is collected in sample plots and along transects placed in representative locations throughout the WAA.

  In collecting the metrics, two 0.04-ha circular plots were established. One subplot was located in the center of the permanent plot and the other 100 m outside the permanent plot. In some instances because of the heterogeneity of the site, additional WAAs were established. GPS readings were taken at the center of each plot for map production and verification of subclass classification.

Data Form 1: Functional Assessment in the Yazoo Basin		
Assessment Team:	**Regional Subclass:**	
Project Name / Location:		**Date:**
Sample the following variables using field reconnaissance, aerial photos, topographic maps, or GIS		
V_{TRACT}	Size of forested wetland that is contiguous with the assessment area	ha
V_{CORE}	Size of wetland tract that is core area	ha
$V_{CONNECT}$	Percent of wetland tract that is connected to "suitable habitat"	%
V_{FREQ}	Overbank flood recurrence interval	years
Sample the following variables based on a walking field reconnaissance of the assessment area		
V_{POND}	Percent of the assessment area with topographic microdepressions that pond water	%
V_{SOIL}	Percent of the assessment area with native and culturally unaltered soils	%
V_{CEC}	Percent difference in CEC in assessment area (from Data Form 2)	%
Transfer plot values for the following variables to this sheet from the Data Forms 3-6		
V_{TBA}	Average tree basal area plot values below (Data Form 3) and record at right Plot 1 ____ m^3/ha Plot 2 ____ m^3/ha Plot 3 ____ m^3/ha	m^2/ha
V_{TDEN}	Average tree density plot values below (Data Form 3) and record at right Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha	stems/ha
V_{SNAG}	Average snag density plot values below (from Data Form 3) and record at right Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha	stems/ha
V_{TCOMP}	Average percent concurrence with dominant trees plot values below (Data Form 4), and record at right Plot 1 __ % Plot 2 __ % Plot 3 __ %	%
V_{COMP}	Average percent concurrence with dominant species in tallest woody stratum plot values below (Data Form 4), and record at right Plot 1 __ % Plot 2 __ % Plot 3 __ %	%
V_{WD}	Average volume of woody debris plot values below (Data Form 5), and record at right Plot 1 ____ m^3/ha Plot 2 ____ m^3/ha Plot 3 ____ m^3/ha	m^3/ha
V_{LOG}	Average volume of log plot values below (Data Form 5), and record at right Plot 1 ____ m^3/ha Plot 2 ____ m^3/ha Plot 3 ____ m^3/ha	m^3/ha
V_{SSD}	Average density of shrub-sapling strata plot values below (Data Form 6), and record at right Plot 1 __ stems/ha Plot 2 __ stems/ha Plot 3 __ stems/ha	stems/ha
V_{GVC}	Average ground vegetation cover plot values below (Data Form 6), and record at right Plot 1 __ % Plot 2 __ % Plot 3 __ %	%
V_{OHOR}	Average thickness of "O" horizon cover plot values below (Data Form 6), and record at right Plot 1 __ cm Plot 2 __ cm Plot 3 __ cm	cm
V_{AHOR}	Average thickness of "A" horizon cover plot values below (Data Form 6), and record at right Plot 1 __ cm Plot 2 __ cm Plot 3 __ cm	cm

Figure 2. Data sheet showing metrics collected at each site (Smith and Klimas 2001)

The sites sampled were all less than 15 years old; therefore several of the variables were not measured. Identification of highest strata present within the plot was the initial step following plot layout. Species were identified and dbh was measured on saplings. Herbaceous vegetation cover was estimated using a 1-m^2 plot at two locations within each sub-plot. The "O" horizon was measured within each of these plots and the "A" horizon was measured at one of the selected subplots. Woody debris was measured along a 15-m transect that began in subplot center. Shrub-sapling density was measured within each subplot on trees with dbh <10 cm and greater than 1.2 m in height. On average, it would take a two-person crew about half an hour to an hour to collect all of the necessary data at each plot.

- Analysis of field data. The raw metrics data were converted into scaled variable scores ranging from 0.0-1.0. These variable scores were then inserted into various Functional Capacity Index (FCI) equations, yielding an FCI score for each function. The FCI score is a value from 0.0-1.0 and is a relative indicator of the capacity of a wetland to perform the given function as compared to other wetlands in an identical regional subclass. The graphs used to scale individual variables and the equations used to calculate FCIs are published in the Yazoo Regional Guidebook.

Sampling Year 2002. As part of a rotational sampling schedule, the Lake George (all planting dates) and Big Twist (1995 planting date) sites were resampled during the summer of 2002. The sampling occurred in the same 0.04-ha plots established in 2001, although a few plots were not resampled for logistical reasons. The only changes in the 2002 sampling protocol were that dbh was only measured for saplings ≥4 in. dbh, and the "A" horizon was not measured, as this value is assumed to have remained constant from the previous year.

RESULTS AND DISCUSSION:

2001 Sampling, Lake George. The Lake George mitigation area contains sites consisting of seven different planting dates in the riverine backwater. Table 2 summarizes the Lake George FCI scores by planting date. In this and subsequent tables and text, the following abbreviations are used for each function:

FCI_{FLOOD} = Detain Floodwater
FCI_{RAIN} = Detain Precipitation
FCI_{NUTR} = Cycle Nutrients
FCI_{ORG} = Export Organic Carbon
FCI_{ELEM} = Remove Elements and Compounds
FCI_{PLANT} = Maintain Characteristic Plant Community
FCI_{FISH} = Provide Fish and Wildlife Habitat

Planting dates were compared statistically using a one-way ANOVA (differences considered significant if $p < 0.05$). There are some significant differences in function among the 1992 to1995 planting dates, but for the most part, functional scores did not vary significantly among the various planting dates.

Table 2
Summary of FCI Scores for Various Planting Dates/Wetland Subclasses at the Lake George Mitigation Site[1]

Function	Planting Date						
	1991	1992	1993	1994	1995	1996	1997
FCI_{FLOOD}	0.26[a,b]	0.26[a,b]	0.38[a]	0.20[b]	0.22[a,b]	0.26[a,b]	0.29[a,b]
FCI_{RAIN}	0.40[a]	0.44[a]	0.52[a]	0.48[a]	0.50[a]	0.50[a]	0.42[a]
FCI_{NUTR}	0.38[a,b]	0.39[a,b]	0.45[a]	0.35[a,b]	0.32[b]	0.38[a,b]	0.39[a,b]
FCI_{ORG}	0.28[a]	0.29[a]	0.35[a]	0.25[a]	0.22[a]	0.28[a]	0.29[a]
FCI_{ELEM}	0.84[a]	0.88[a]	0.87[a]	0.88[a]	0.80[a]	0.84[a]	0.83[a]
FCI_{PLANT}	0.52[a,b]	0.49[a]	0.55[a,b]	0.57[a,b]	0.62[b]	0.56[a,b]	0.53[a,b]
FCI_{FISH}	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]

[1] Values in the same row followed by the same letter(s) are statistically similar ($p > 0.05$).

2001 Sampling, Big Twist. The Big Twist mitigation site contains sites consisting of three different planting dates and two wetland subclasses (riverine backwater and flats). Table 3 summarizes the Big Twist FCI scores by planting date for both the flats subclass and the riverine backwater subclass. Statistical comparisons were again made using a one-way ANOVA. Overall, the 1995 planting appears to have the highest level of functioning. This is attributable to large portions of the 1995 planting being located in the 1- and 2-year floodplains, which resulted in a significant functional lift in the FCI_{FLOOD}, FCI_{ORG}, and FCI_{ELEM} functions over the 1996 and 1997 planting dates, which were located primarily in the 3- to 5-yr floodplain. Functions among the flats, however, were statistically similar across the three planting dates.

Table 3
FCI Scores for Various Planting Dates/Wetland Subclasses at the Big Twist Mitigation Site[1]

Function	1995	1996	1997
Riverine Backwater Subclass			
FCI_{FLOOD}	0.28[a]	0.10[b]	0.12[b]
FCI_{RAIN}	0.58[a]	0.26[b]	0.60[a]
FCI_{NUTR}	0.46[a]	0.42[a]	0.44[a]
FCI_{ORG}	0.30[a]	0.10[b]	0.12[b]
FCI_{ELEM}	0.74[a]	0.19[b]	0.33[b]
FCI_{PLANT}	0.48[a]	0.53[b]	0.61[b]
FCI_{FISH}	0.00[a]	0.00[a]	0.00[a]
Flats Subclass			
FCI_{RAIN}	0.60[a]	0.56[a]	0.56[a]
FCI_{NUTR}	0.40[a]	0.41[a]	0.46[a]
FCI_{PLANT}	0.30[a]	0.43[a]	0.42[a]
FCI_{FISH}	0.00[a]	0.00[a]	0.00[a]

[1] Values in the same row followed by the same letter(s) are statistically similar ($p > 0.05$).

2001 Sampling, Darlove, Skylake, Polutken. The Darlove, Skylake, and Polutken mitigation areas are all single planting date sites. Table 4 summarizes the FCI scores for each of these sites by wetland subclass.

2002 Sampling. Tables 5 and 6 are comparisons of FCI scores between the 2001 and 2002 planting dates at the Lake George and Big Twist mitigation sites. Statistical comparisons were made using a two sample T- test (differences significant if a two-tailed $p < 0.05$).

Although some planting dates at both sites showed significant increases in specific functions, for the most part functional index scores were similar between the 2001 and 2002 samplings.

Table 4
FCI Scores for Various Planting Dates/Wetland Subclasses at the Darlove, Polutken, and Skylake Mitigation Sites

Darlove, 1998		
	Wetland Subclass	
Function	Flats	Connected Depressions
FCI_{FLOOD}		0.01
FCI_{RAIN}	0.48	
FCI_{NUTR}	0.35	0.03
FCI_{ORG}		0.01
FCI_{ELEM}		0.50
FCI_{PLANT}	0.36	0.71
FCI_{FISH}	0.00	0.00

Polutken, 1998		
	Wetland Subclass	
Function	Flats	Isolated Depressions
FCI_{FLOOD}		
FCI_{RAIN}	0.67	
FCI_{NUTR}	0.30	0.10
FCI_{ORG}		
FCI_{ELEM}		
FCI_{PLANT}	0.27	0.20
FCI_{FISH}	0.00	0.00

Skylake, 1999			
	Wetland Subclass		
Function	Flats	Connected Depressions	Riverine Backwater
FCI_{FLOOD}		0.16	0.26
FCI_{RAIN}	0.48		0.42
FCI_{NUTR}	0.32	0.13	0.33
FCI_{ORG}		0.11	0.24
FCI_{ELEM}		0.83	0.56
FCI_{PLANT}	0.40	0.71	0.50
FCI_{FISH}	0.00	0.00	0.00

Wetland Functional Recovery. Tables 1-4 report functional capacity of the sites as of 2001. However, in order to determine *changes* in functioning, these values need to be compared to functional capacity of the sites prior to restoration. Because no baseline HGM data were collected at the sites before they were restored, certain assumptions need to be made about the condition of sites prior to planting. Prior to restoration, it is assumed that values for shrub-sapling density, ground vegetation cover, small woody debris volume, and organic horizon depth are all zero. In the early years following restoration, changes in these metrics should be the primary force driving increases in function. Any metric relating to trees (trees defined as individuals >4 in. dbh) is also assumed to have a value of zero prior to restoration. For the most part, as of 2001 these values remain at zero since sites are still not old enough to have trees >4 in. dbh. Finally, because no hydrologic or topographic modifications were made at any of the sites, it is assumed that metrics such as soil integrity, microdepressional ponding, and flood frequency were the same prior to planting as they

Table 5
Comparison of FCI Scores Between Sampling Years for the 1995 Planting Date at the Big Twist Mitigation Site[1]

Function	Wetland Subclass			
	Flats		Riverine Backwater	
	Sampling Date			
	2001	2002	2001	2002
FCI_{FLOOD}			0.28	0.30
FCI_{RAIN}	0.60	0.60	0.58	0.58
FCI_{NUTR}	0.40	0.50	0.46	0.52
FCI_{ORG}			0.30	0.34
FCI_{ELEM}			0.74	0.74
FCI_{PLANT}	0.30	0.33	0.48	0.48
FCI_{FISH}	0.00	0.00	0.00	0.00

[1] For each subclass, values in the same row in bold type are statistically different ($p < 0.05$).

Table 6
Comparison of FCI Scores Between Sampling Years at the Lake George Mitigation Site[1]

Function	Planting Date													
	1991		1992		1993		1994		1995		1996		1997	
	Sampling Year													
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
FCI_{FLOOD}	0.26	0.25	0.26	0.34	0.22	0.26	0.26	0.26	0.29	0.33	0.38	0.42	0.20	0.30
FCI_{RAIN}	0.40	0.38	0.44	0.44	0.50	0.50	0.50	0.50	0.42	0.42	0.52	0.56	0.48	0.50
FCI_{NUTR}	0.38	0.35	0.39	0.43	0.32	0.42	0.38	0.38	0.39	0.42	0.45	0.46	0.35	0.40
FCI_{ORG}	0.28	0.28	0.29	0.33	0.22	0.34	0.28	0.28	0.29	0.33	0.35	0.36	0.25	0.30
FCI_{ELEM}	0.84	0.85	0.88	0.88	0.80	0.80	0.84	0.84	0.83	0.82	0.87	0.88	0.88	0.88
FCI_{PLANT}	0.52	0.50	0.49	0.50	0.62	0.58	0.56	0.52	0.53	0.52	0.55	0.56	0.57	0.54
FCI_{FISH}	0.00	0.05	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02

[1] For each planting date, values in bold type in the same row are statistically different ($p < 0.05$).

are today. Based on these assumptions, it is possible to calculate FCI scores for the sites prior to replanting. Table 7 shows the differences between these scores and those calculated for 2001 (for Lake George and Big Twist, the average scores across planting dates were used) for each site, by subclass. Because they are largely dependent on vegetation-related metrics (which are the variables more likely to change early on) the largest increases are seen in the FCI_{PLANT}, followed by the FCI_{NUTR} and FCI_{FLOOD} functions.

Larger increases in the FCI_{NUTR}, FCI_{ORG}, FCI_{FISH}, and FCI_{PLANT} functions can be expected once sites are old enough to contain trees (>4 in. dbh). In particular, the FCI_{FISH} function requires either trees or snags in order to have any value >0.0. Smaller increases are expected in the FCI_{FLOOD}, FCI_{RAIN}, and FCI_{ELEM} functions, since measurement of these functions involves variables (such as flood frequency) that are less likely to change over time. However, in some cases (FCI_{ELEM} in the Sky Lake connected depressions, for instance) these functions are already being performed at a relatively high level.

Table 7
Differences in FCI Between 2001 and Pre-planting at Each Mitigation Site ((FCI 2001) – (FCI pre-planting))[1]

	Mitigation Site									
	Lake George	Big Twist		Darlove		Polutken		Skylake		
	Wetland Subclasses									
Function	Riverine Backwater	Flats	Riverine Backwater	Flats	Connected Depressions	Flats	Isolated Depressions	Flats	Riverine Backwater	Connected Depressions
FCI_{FLOOD}	0.3		0.2		0				0.3	0.2
FCI_{RAIN}	0.1	0.2	0.1	0		0		0	0	
FCI_{NUTR}	0.2	0.2	0.2	0.2	0	0.1	0.1	0.2	0.2	0.1
FCI_{ORG}	0.1		0.2		0				0.1	0.1
FCI_{ELEM}	0.1		0		0				0	0
FCI_{PLANT}	0.6	0.4	0.5	0.4	0.7	0.3	0.2	0.4	0.6	0.7
FCI_{FISH}	0	0	0	0	0	0	0	0	0	0

[1] Values have been rounded to the nearest first decimal point.

Figure 3 shows the projected functional recovery over a period of 60 years for a hypothetical restored riverine backwater site. These curves are based on recovery trajectories for tree basal area, tree, shrub-sapling, and snag density, ground vegetation cover, log and woody debris volume, and 'O' horizon depth, published in the Yazoo Regional Guidebook, and are derived from data collected at actual sites. The curves are also based on the assumption that the site is at least 3000 ha with a minimum of 40 percent core area and 40 percent connectivity to other wildlife habitat. It is also assumed that the composition of tree species does not alter significantly from what was originally planted, and that the site is within the 2-year floodplain.

Table 8 compares the FCI scores of the 5- and 10-year-old (as of 2002) Lake George plantings with the projected 5- and 10-year FCI scores depicted in Figure 3. At the 5-year-old site, the actual FCI values generally exceed the projected values, with the exception of the FCI_{PLANT} function (due to the planted tree composition at the actual site, as well as the introduction of some volunteer species). However, scores at the 10-year-old planting tended to be slightly lower than the projected values, which is due primarily to a lower-than-projected shrub-sapling density.

CONCLUSIONS: Monitoring of restoration projects is critical for determining whether or not recovery of desirable wetland functions is occurring at a given site. The HGM method as presented in this technical note allows for functional assessment to occur in an effective and cost-efficient manner. The method is also sensitive enough that it can detect functional changes in a single year (Table 6).

Results from preliminary monitoring efforts indicate that functional recovery is occurring at the Vicksburg District wetland mitigation sites (Table 7), although some functions are recovering more rapidly than others. Based on Figure 3, it is expected that sites will continue to show a sharp and rapid increase in function between 10 and 20 years of age, and by age 40 will achieve near full functional recovery (FCI = 1.0) of the cycle nutrients, detain precipitation, maintain plant community, and provide fish and wildlife habitat functions. The other functions may or may not

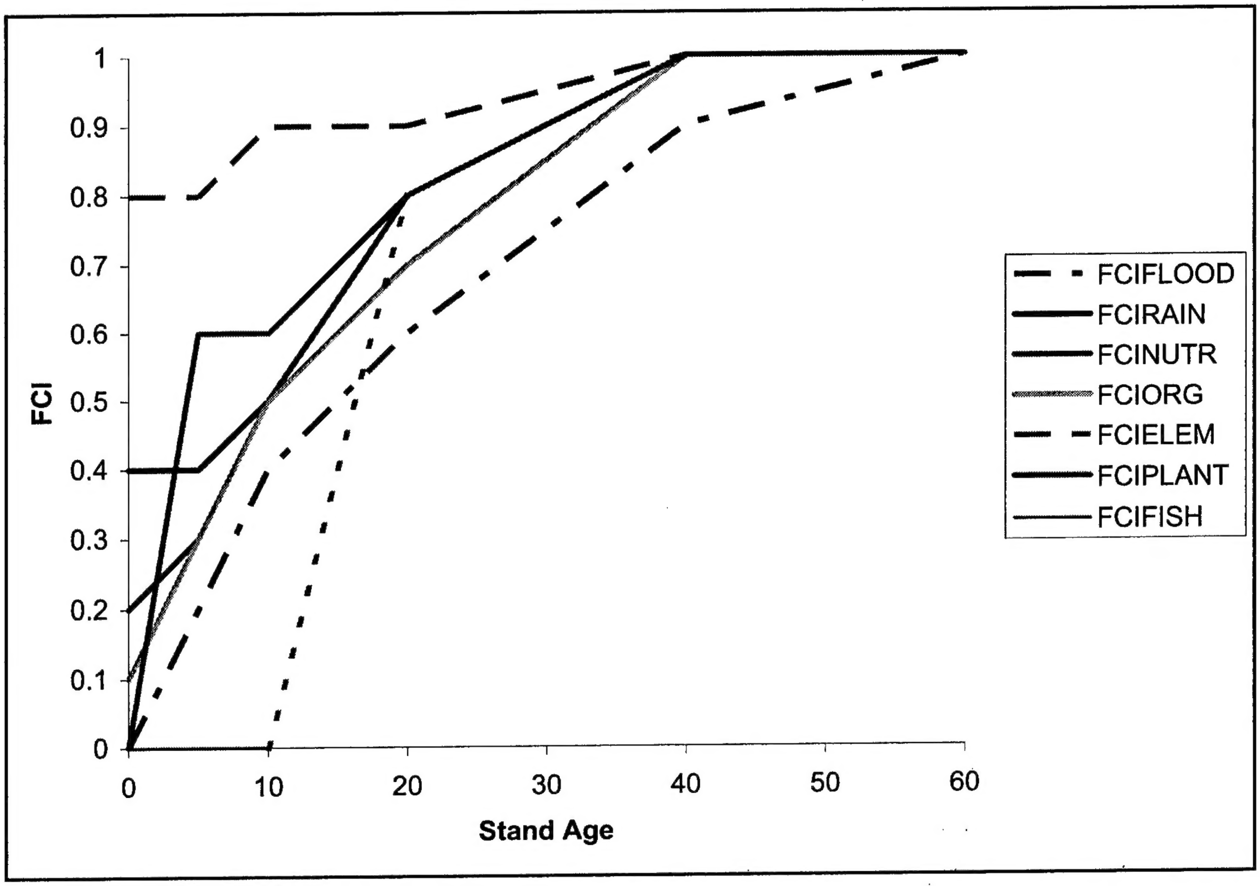

Figure 3. Functional recovery trajectories of a hypothetical riverine backwater restoration site

Table 8
Comparison of FCI Scores From Lake George and a Hypothetical Riverine Backwater Restoration Site at 5 and 10 Years After Planting

Function	5 Years Old		10 Years Old	
	Actual	Projected	Actual	Projected
FCI_{FLOOD}	0.33	0.2	0.34	0.4
FCI_{RAIN}	0.42	0.4	0.44	0.5
FCI_{NUTR}	0.42	0.3	0.43	0.5
FCI_{ORG}	0.33	0.3	0.33	0.5
FCI_{ELEM}	0.82	0.8	0.88	0.9
FCI_{PLANT}	0.52	0.6	0.5	0.6
FCI_{FISH}	0	0	0.06	0

reach full recovery (or may not be performed at all in he case of Flats and Isolated Depression subclasses), depending on the flood frequency at each site. However, since these sites are still relatively young, continued monitoring is necessary in order to ensure that functional recovery is still occurring as expected.

POINTS OF CONTACT: This technical note was written by Ms. Monica N. Humphrey at the USACE, Vicksburg District, and Mr. Jeff P. Lin, Dr. Barbara A. Kleiss, and Mr. Darrell E. Evans at the Engineer Research and Development Center, Vicksburg, MS. For additional information, contact Mr. Lin (601-634-2068, Jeff.P.Lin@erdc.usace.army.mil). This technical note should be cited as follows:

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REFERENCES

Brinson, M.M. (1993). "A hydrogeomorphic classification for wetlands," Technical Report WRP-DE-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Saucier, R.T. (1994). "Geomorphology and quaternary geologic history of the Lower Mississippi Valley," Vol I (report), Vol II (map folio), U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smith, R.D., and Klimas, C.V. (2002). "A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of selected regional wetland subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley," ERDC/EL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS.